Electro-optical transfer
characteristic of reference
reproducer:
$$L = ((V+0.1115)/1.1115)^{(1/0.45)} \quad \text{for } V \geq 0.0913$$
$$L = V/4.0 \quad \text{for } V < 0.0913$$

Opto-electronic transfer
characteristic of reference
camera:
$$V = 1.1115 \cdot L^{(.45)} - 0.1115 \quad \text{for } L \geq 0.0228$$
$$V = 4.0 \cdot L \quad \text{for } L < 0.0228$$

where L = light output from reproducing primary
V = video signal driving the reproducing primary
(Ref. ARD Document Pflichtenheft Nr. 8/4, §4.1.8)

4. Reference Clock

Signal durations and timings are specified both in microseconds and in reference clock periods.

Reference clock periods in total line: 2200
Reference clock frequency (derived): 74.25 MHz

5. Video Signal Definitions

The video signals shall be appropriate to drive the reference reproducer.
Picture sources shall incorporate colorimetric analysis and signal processing to achieve this end.

The image is represented by three parallel, time-coincident video signals. Each incorporates a synchronizing waveform.

The signals shall be either of the following sets:

Color Set	Color Difference Set
G - "green"	Y - "luminance"
B - "blue"	P_B- "blue color difference"
R - "red"	P_R- "red color difference"

where [G B R] are the signals appropriate to directly drive the primaries of the reference reproducer (having been pre-corrected for the reproducer's electro-optical transfer characteristic), and [Y P_B P_R] can be derived from [G B R] through a linear matrix.

More specifically,

$$Y = 0.701 \cdot G + 0.087 \cdot B + 0.212 \cdot R$$

P_B is amplitude-scaled (B-Y), according to:

$$P_B = (B-Y)/1.826$$

and P_R is amplitude-scaled (R-Y), according to:

$$P_R = (R-Y)/1.576$$

where the scaling factors are derived from the signal levels given in section 6.3 and the following transformation equations.

The derived transformation between the two sets is:

$$\begin{bmatrix} G \\ B \\ R \end{bmatrix} = \begin{bmatrix} 1.000 & -0.227 & -0.477 \\ 1.000 & 1.826 & 0.000 \\ 1.000 & 0.000 & 1.576 \end{bmatrix} \begin{bmatrix} Y \\ P_B \\ P_R \end{bmatrix}$$

$$\begin{bmatrix} Y \\ P_B \\ P_R \end{bmatrix} = \begin{bmatrix} 0.701 & 0.087 & 0.212 \\ -0.384 & 0.500 & -0.116 \\ -0.445 & -0.055 & 0.500 \end{bmatrix} \begin{bmatrix} G \\ B \\ R \end{bmatrix}$$

6. Video and Synchronizing Signal Waveforms

The combined video and synchronizing signal shall be as shown in Figure 1. For illustrative purposes, a video signal of the form Y, G, B, or R is shown. The details of the synchronizing signal are identical for the P_B and P_R color difference signals.

6.1 Timing

The timing of events within a horizontal line of video is illustrated in Figure 1(a) and summarized in the following table. All event times are specified at the midpoint of the indicated transition.

Rising edge of sync (timing reference)	0
Trailing edge of sync	44
Start of active video	192
End of active video	2112
Leading edge of sync	2156

The durations of the various portions of the video and sync waveforms are illustrated in Figure 1(b), (c), and (d), and summarized in the following table.

	reference clock periods	time (derived) (microsec.)
a	44	0.593
b	88	1.185
c	44	0.593
d	132	1.778
e	192	2.586
f (Sync rise time)	4	0.054
Total line	2200	29.63
Active line	1920	25.86

6.2 Bandwidth

The Color Set [G B R] comprises three equal-bandwidth signals whose nominal bandwidths are 30 MHz.

The Color Difference Set [Y P_B P_R] comprises a luminance signal Y whose nominal bandwidth is 30 MHz and color difference signals P_B and P_R whose nominal bandwidths are 30 MHz for analog originating equipment and 15 MHz for digital originating equipment.

6.3 Analog Representation

The video signals are represented in analog form as follows:

Y,G,B,R Signals

Reference Black level	(mV)	0
Reference White level	(mV)	700
Synchronizing level	(mV)	±300

P_B,P_R signals

Reference zero signal level	(mV)	0
Reference peak levels	(mV)	±350
Synchronizing level	(mV)	±300

6.4 Digital Representation

See Appendix 2.

Reference clock periods: 0 44 192 2112 2156 2200

Time (µsec.) (derived): 0 0 59 2 59 28 44 29 04 29 63
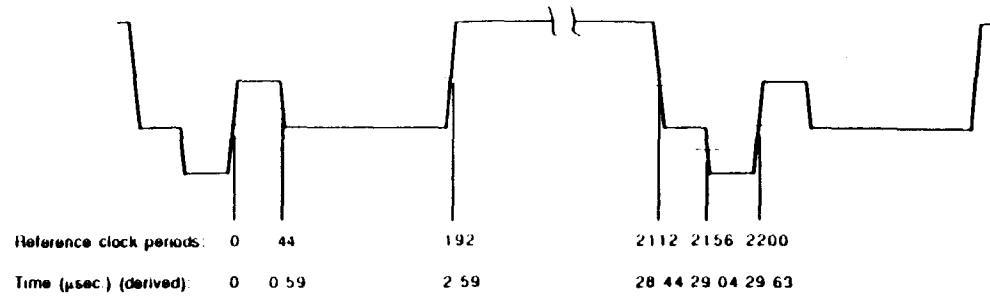
Figure 1(a). Timing of events within a video line.

vertical sync
timing reference
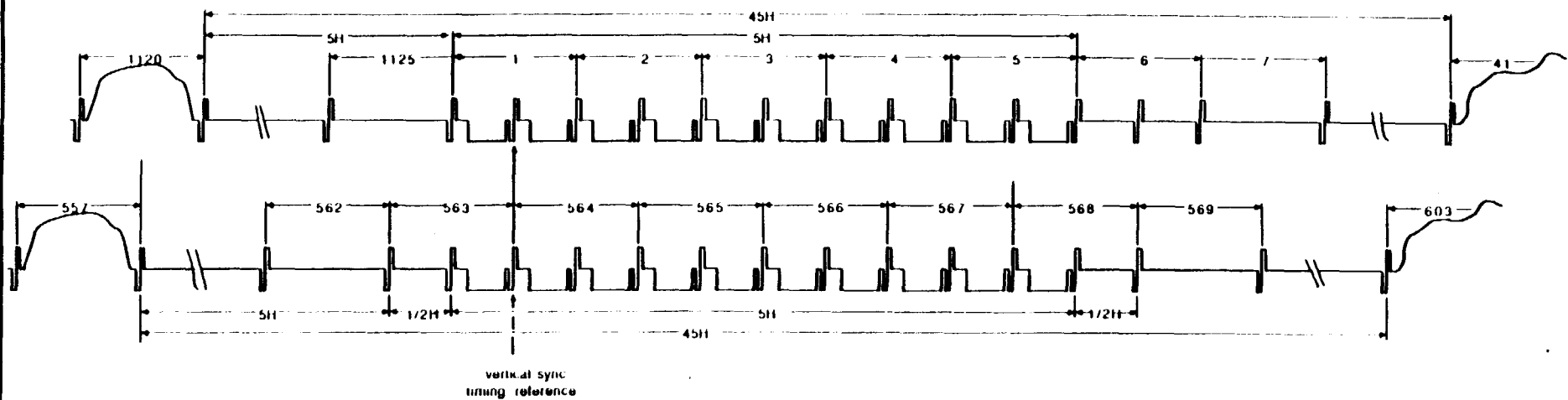
Figure 1(b). Detail of field blanking periods.

horizontal sync
timing reference

V = reference white level
S = synchronizing level
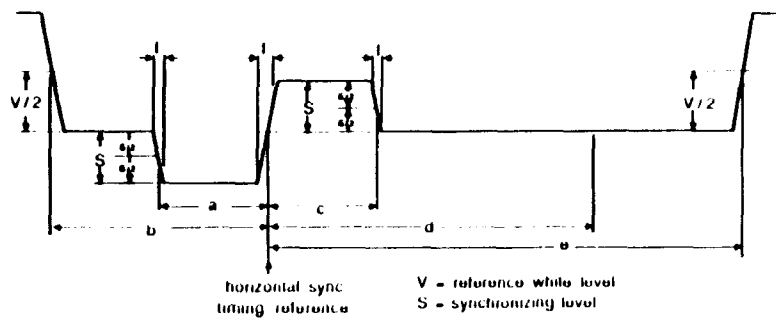
Figure 1(c). Detail of line blanking period
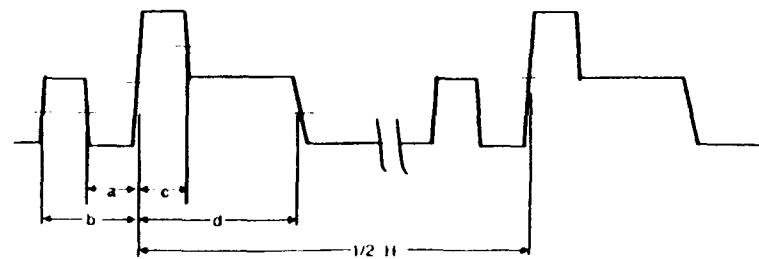
Figure 1(d). Detail of field synchronizing pulse.

Appendix 1

System Colorimetry

The parameters values in section 3 are based on current practice and technical constraints.

It is recognized that it would be desirable to implement a system embracing a wider color gamut, and embodying the principle of "constant luminance."

Before this can be done, further study is required, in particular of the feasibility of implementing non-linear signal processing at various points throughout the system.

With respect to color gamut, it is felt that the system should embrace a gamut at least as large as that represented by the following primaries:

$$G: \quad x = 0.210 \quad y = 0.710$$
$$B: \quad x = 0.150 \quad y = 0.060$$
$$R: \quad x = 0.670 \quad y = 0.330$$

Appendix 2 .

This appendix is not part of the draft standard, but is included for information only.

Digital Representation

It is necessary to define the digital representation of the 1125/60 HDTV signal. Current practice and experience have not clarified the most suitable value for certain parameters, in particular the number of bits per sample and the coding law. An appropriate form for the specifications of section 6.4 would be the following:

		Y,G,B,R signals	P_B,P_R signals
Quantization	(bits)	[ ]	[ ]
Coding Law		[ ]	[ ]
Sampling frequency	(MHz)	74.25	37.125
Samples per active line		1920	960

The sampling structure is orthogonal: line, field and frame repetitive.

Appendix 3

This appendix is not part of the draft standard, but is included for information only.

Tolerances

The Ad-Hoc Group did not choose to affix tolerances to any of the parameters specified in this document. It was felt that this document specifies aim points for system design, rather than detailed system specifications. Furthermore, it was not possible to determine comprehensive tolerances for all parameters on the basis of information at the disposal of the Ad-Hoc Group. It was concluded that tolerancing should be left to future documents which give detailed specifications for specific components or equipment operating in the 1125/60 HDTV system.

However, in the course of debating the document, certain tolerances were discussed. These will be given in this appendix, in order that the information should not be lost.

Line Repetition Rate

The Ad-Hoc Group had initially attached a tolerance to this parameter, to serve as a fundamental tolerance on all system timing. This tolerance was removed as a consequence of the decision to leave the document untoleranced. The stated value, with tolerance, was:

Line Repetition Rate (derived)	33750.00 Hz ±10 ppm

Synchronizing Signal

The synchronizing signal adopted by the Ad-Hoc Group was that proposed by BTA (Japan). The BTA proposal was based on time durations, which were toleranced. The Ad-Hoc Group chose counts of reference clock periods as the primary time specification, giving time durations in microseconds as derived, and quoting no tolerances. For information, the BTA proposal, with tolerances, was:

a	0.593 ±0.040 microsec
b	1.185 ±0.040 microsec
c	0.593 ±0.040 microsec
d	1.778 ±0.040 microsec
e	2.586 ±0.040 microsec
f (sync rise time)	0.054 ±0.020 microsec
S sync pulse amplitude	300 ±6 mV
amplitude difference between positive and negative-going sync pulses	<6 mV

Appendix 4

Relationships between basic and derived parameters

In this document, certain parameters have been determined as basic and fundamental system parameters. The values of all other system parameters can be derived from those chosen as basic. The purpose of this appendix is to describe and define the derivations.

Line Repetition Rate (L):

$$L = S \cdot F / 2$$

where F = field repetition rate (section 2),
and S = total scan lines per frame (section 2).

Reference Clock Frequency (C):

$$C = L \cdot R$$

where L = line repetition rate (section 2, derived above),
and R = reference clock periods in total line (section 4).

Transformation Matrices between component sets (section 5):

The transformation matrices can be calculated from the chromaticity coordinates of the reproducer primaries, and the chromaticity of reference white (ie. the color reproduced when the reference reproducer is driven by equal primary signals), according to well-known methods.

Stated briefly, the equation for Y can be found as follows:

$$Y = (G \cdot L_g \cdot y_g) + (B \cdot L_b \cdot y_b) + (R \cdot L_r \cdot y_r)$$

where L_g, L_b, and L_r are derived as follows:

$$\begin{bmatrix} L_r \\ L_g \\ L_b \end{bmatrix} = \begin{bmatrix} x_r & x_g & x_b \\ y_r & y_g & y_b \\ z_r & z_g & z_b \end{bmatrix}^{-1} \begin{bmatrix} x_w/y_w \\ 1 \\ z_w/z_w \end{bmatrix}$$

and: x_r, y_r, z_r are the chromaticity coordinates of the red primary,
x_g, y_g, z_g are the chromaticity coordinates of the green primary,
x_b, y_b, z_b are the chromaticity coordinates of the blue primary,
x_w, y_w, z_w are the chromaticity coordinates of reference white.

Exhibit 5

ANALYSIS OF REQUIRED SPECTRUM BANDWIDTH FOR HDTV TRANSMISSION

Question 2 of the Notice of Inquiry asks: "[C]an ATV technologies be expected to develop so that the transmission bandwidth of a high resolution production source can be compressed to fit within 6 MHz channel without apparent loss of quality?" At this time, the ATSC has insufficient information to answer this question definitively. Innovative bandwidth compression techniques are being utilized in various transmission systems in an effort to achieve an appropriate balance between picture quality and spectrum requirements. It should be noted, however, that HDTV is generally defined as having spatial resolution in the vertical and horizontal directions of about twice that of current TV systems, along with improved color rendition, separate color-difference and luminance signals, a wider aspect ratio, and multiple-channel high fidelity sound[1]. If one assumes these requirements for the transmitted HDTV signal, the bandwidth ("BW") of the luminance portion of the HDTV signal becomes:

$$BW = 2 \times 2 \times (16/9)/(4/3) \times 4.2 \text{ MHz} = 22.4 \text{ MHz}.$$

The HDTV luminance bandwidth, compared to the 4.2 MHz luminance bandwidth of the NTSC signal, is increased by two factors of two because of the doubled vertical and horizontal resolution and by the degree to which the HDTV aspect ratio, 16:9, exceeds the NTSC aspect ratio, 4:3.

Recognizing that 22.4 MHz bandwidth is required merely for the luminance signal[2], it seems clear that the task of compressing this amount of information to "fit within 6 MHz channel without apparent loss of quality" will be difficult.

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[1] For a more detailed discussion of the distinguishing characteristics of HDTV, see CCIR Report 801-2, "The Present State of High-Definition Television," Recommendations and Reports of the CCIR, 1986, Volume XI, Part 1, Broadcasting Service (Television), Page 43.

[2] An additional bandwidth of 5-10 MHz would be needed for the separate color-difference signals and about 0.6 MHz would be needed for high fidelity digital stereo sound. The total bandwidth would then be about 28-33 MHz.

Exhibit 6

ATSC TEST PROGRAM - PHASE I - SIGNAL PROPAGATION TESTS

The first phase of the ATSC's test and evaluation program began on September 30, 1987. The television signal transmitted daily by operating station WUSA-TV, Channel 9, Washington, DC, is also being transmitted on Channel 58 from the WUSA-TV tower. Special test signals contained in the vertical blanking interval of the television signal will be measured at multiple remote points to compare propagation characteristics of the two widely separated TV channels. These test transmissions will be conducted during the fourth quarter of 1987.

This particular test was designed to determine differences which might be encountered in the propagation of two separate signals, both of which would be required to transmit a high definition television signal and then combined to form a single HDTV picture at the point of reception. Many tests have been conducted in the past to determine propagation characteristics of VHF and UHF channels, but the tests have not attempted to measure subtle differences which must be known if two separate channels are each used to carry a portion of a total signal.

The next step in this phase of the test program is expected to begin in January 1988. A signal containing frequency components which exceed the normal 6 MHz bandwidth will be transmitted in Washington, DC using Channel 58 and Channel 59 as a single wide-band channel. The purpose of this test will be to determine the propagation characteristics of a signal with a bandwidth greater than the NTSC specification of 6 MHz. Little information currently exists concerning propagation characteristics of such signals in these bands. For example, multi-path studies in the past have concentrated on measuring characteristics which pertain to the NTSC signal. Reflections which would not be visible with the NTSC system could prevent acceptable reception with a wide-band signal. Information of this nature is required to analyze wide-band systems which could be proposed for high definition television broadcasting. These measurements are scheduled to be conducted during the first six months of 1988.

Also beginning in January 1988 and conducted in Washington, DC, a signal containing frequency components which exceed the normal 6 MHz bandwidth will be transmitted in a 12 MHz channel in the 12 GHz band. Some data of this type are already available from a study conducted in San Francisco in 1982, but that work must be updated and expanded in light of more recent knowledge of the bandwidth requirements for HDTV transmission.

During these initial tests information will be gathered which will be used to define further steps required to fully determine the propagation characteristics of the spectrum being measured. The influence of different field conditions, such as topography, weather conditions, and urban environments will be determined. Subsequent tests will be conducted at a number of appropriate geographic locations.

Exhibit 7

CONSIDERATIONS FOR SUBJECTIVE ASSESSMENT OF PROPOSED HDTV TRANSMISSION SYSTEMS

Proper subjective assessment of proposed HDTV transmission systems will involve the careful selection of viewers, and the use of numbers and types of viewers sufficient to obtain statistically valid results. The following categories of viewers must be considered:

1. Heavy and light viewing habits.

2. Heavy and light movie attendance.

3. Various educational levels.

4. Male and female.

5. Various age groups.

6. Persons involved in the graphic arts.

The specific test conditions must be carefully and realistically defined. The following viewing conditions must be considered:

1. The distance of the viewer from the display.

2. The size of the display.

3. The brightness of the display.

4. The room lighting (ambient illuminance).

5. The selection of visual stimuli in the program material.

6. The portrayal of motion in the program material.